CLAIMS

I claim:

1. A method for surveying a borehole, the method comprising:

(a) providing a downhole tool including first and second magnetic field measurement devices disposed at corresponding first and second positions in the borehole, the first and second positions selected to be within sensory range of magnetic flux from a target subterranean structure;

(b) measuring local magnetic fields at the first and second positions using the corresponding first and second magnetic field measurement devices;

(c) processing (1) the local magnetic fields at the first and second positions, and (2) a reference magnetic field, to determine a portion of the local magnetic fields attributable to the target subterranean structure;

(d) generating interference magnetic field vectors at the first and second positions from the portion of the local magnetic fields attributable to the target subterranean structure; and

(e) processing the interference magnetic field vectors to determine a tool face to target angle at each of the first and second positions, the tool face to target angles representing a corresponding direction from each of the first and second positions to the target subterranean structure.

2. The method of claim 1, wherein the target subterranean structure is a cased borehole.

3. The method of claim 1, wherein the downhole tool further comprises gravity measurement devices disposed at each of the first and second positions.

4. The method of claim 1, wherein the reference magnetic field is measured at a site substantially free of magnetic interference.

5. The method of claim 1, wherein the reference magnetic field is known based on a historical geological survey.

6. The method of claim 1, wherein the reference magnetic field is determined from a numerical model.

7. The method of claim 1, wherein (b) comprises measuring first and second magnetic field vectors at each of the first and second positions.

8. The method of claim 1, wherein (b) comprises measuring two-dimensional local magnetic fields at each of the first and second positions.

9. The method of claim 1, wherein (d) comprises generating two-dimensional interference magnetic field vectors at each of the first and second positions.

10. The method of claim 1, wherein x and y components of the reference magnetic field are determined according to the equations:

$$M_{EX} = H_E(\cos D \sin Az \cos R + \cos D \cos Az \cos Inc \sin R - \sin D \sin Inc \sin R)$$

$$M_{EY} = H_E(\cos D \cos Az \cos Inc \cos R + \sin D \sin Inc \cos R - \cos D \sin Az \sin R)$$

wherein Mex and Mey represent the x and y components of the reference magnetic field, respectively, He represents a magnitude of the reference magnetic field, D represents a magnetic dip of the reference magnetic field, Inc represents a local borehole inclination, Az represents a local borehole azimuth, and R represents a local rotation of the downhole tool.

11. The method of claim 10, wherein:

the downhole tool further comprises gravity measurement devices disposed at each of the first and second positions; and

Inc and R are determined via gravity measurements at the first and second positions.

12. The method of claim 10, wherein Az is determined from a historical survey of the target subterranean structure.

13. The method of claim 1, wherein (c) comprises determining a difference between the local magnetic field and the reference magnetic field at each of the first and second positions.

14. The method of claim 13, wherein:

x and y components of the reference magnetic field are determined according to the equations:

$$M_{EX} = H_E(\cos D \sin Az \cos R + \cos D \cos Az \cos Inc \sin R - \sin D \sin Inc \sin R)$$

$$M_{EY} = H_E(\cos D \cos Az \cos Inc \cos R + \sin D \sin Inc \cos R - \cos D \sin Az \sin R)$$

wherein Mex and Mey represent the x and y components of the reference magnetic field, respectively, He represents a magnitude of the reference magnetic field, D represents a magnetic dip of the reference magnetic field, Inc represents a local borehole inclination, Az represents a local borehole azimuth, and R represents a local rotation of the downhole tool; and

the portion of the local magnetic field attributable to the target subterranean structure is determined according to the equations:

$$M_{IX} = B_X - M_{EX}$$

$$M_{IY} = B_Y - M_{EY}$$

wherein Mix and Miy represent x and y components, respectively, of the portion of the local magnetic field attributable to the target subterranean structure, and Bx and By represent x and y components of the local magnetic field, respectively.

15. The method of claim 14, wherein (c) further comprises subtracting another magnetic field component from the difference between the local magnetic field and the reference magnetic field.

16. The method of claim 1, wherein (e) comprises processing x and y components of the interference magnetic field vectors, the x and y components being orthogonal to a longitudinal axis of the borehole.

17. The method of claim 1, wherein the tool face to target angle at each of the first and second positions is determined according to the equation:

$$TFT = \arctan(\frac{M_{IX}}{M_{IY}}) + \arctan(\frac{Gx}{Gy})$$

wherein TFT represents the tool face to target angle, Mix and Miy represent the x and y components, respectively, of the magnetic interference vector, and Gx and Gy represent x and y components of gravity vectors measured at at least one of the first and second positions.

18. The method of claim 1, further comprising:

(f) determining a tool face to target angle at a third position in the borehole by extrapolating the tool face to target angles at the first and second positions determined in (e).

19. The method of claim 18, wherein a drill bit assembly is located at the third position.

20. The method of claim 1, further comprising:

(f) displaying the tool face to target angles versus a measured depth of the borehole.

21. The method of claim 1, further comprising:

(f) processing the tool face to target angles at the first and second positions to determine a local direction of the borehole relative to the target subterranean structure.

22. The method of claim 21, further comprising:

(g) processing the tool face to target angles determined in (e) and the local direction of the borehole determined in (f) to determine a subsequent direction of drilling the borehole.

23. The method of claim 1, further comprising:

(f) changing tool face by rotating the downhole tool in the borehole;

(g) repeating (b), (c), (d), and (e);

24. The method of claim 23, further comprising:

(h) comparing the tool face to target angles determined in (e) with the tool face to target angles determined in (g).

25. The method of claim 1, further comprising:

(f) processing the local magnetic fields at the first and second positions and the reference magnetic field to determine an interference magnetic dip at the first and second positions; and

(g) comparing the interference magnetic dips determined in (f) with the tool face to target angles determined in (e).

26. A method for surveying a borehole, the method comprising:

(a) providing a downhole tool including a magnetic field measurement device disposed at a first position in the borehole, the first position selected to be within sensory range of magnetic flux from the subterranean structure;

(b) measuring a local magnetic field at the first position using the magnetic field measurement device;

(c) re-positioning the tool at a second position in the borehole so that the magnetic field measurement device remains within sensory range of the magnetic flux from the subterranean structure;

(d) measuring a local magnetic field at the second position using the magnetic field measurement device;

(e) processing the local magnetic fields at the first and second positions and a reference magnetic field to determine a portion of the local magnetic fields attributable to the target subterranean structure;

(f) generating interference magnetic field vectors at the first and second positions from the portion of the local magnetic fields attributable to the target subterranean structure; and

(g) processing the interference magnetic field vectors to determine a tool face to target angle at each of the first and second positions, the tool face to target angles representing a direction from the first and second positions to the subterranean structure.

27. The method of claim 26, further comprising:

(h) processing the tool face to target angles determined in (g) to determine distance from at least one of the first and second positions in the borehole and to the target subterranean structure.

28. The method of claim 26, further comprising:

(h) processing the tool face to target angles determined in (g) to determine a local azimuth of the borehole.

29. The method of claim 28, wherein (h) further comprises:

(1) processing the tool face to target angles at the first and second positions to determine distance from the borehole to the target subterranean structure;

(2) processing the tool face to target angles at the first and second positions and the distance from the borehole to the target subterranean structure to determine coordinates of the first and second positions in the borehole; and

(3) processing the coordinates of the first and second positions in the borehole to determine a local azimuth of the borehole.

30. A method for determining distance from a borehole to a target subterranean structure, the method comprising:

(a) providing a downhole tool including first and second magnetic field measurement devices disposed at corresponding first and second positions in the borehole, the first and second positions selected to be within sensory range of magnetic flux from the target subterranean structure;

(b) measuring local magnetic fields at the first and second positions using the corresponding first and second magnetic field measurement devices;

(c) processing (1) the local magnetic fields at the first and second positions, and (2) a reference magnetic field, to determine a portion of the local magnetic fields attributable to the target subterranean structure;

(d) generating interference magnetic field vectors at the first and second positions from the portion of the local magnetic fields attributable to the target subterranean structure;

(e) processing the interference magnetic field vectors to determine a tool face to target angle at each of the first and second positions; and

(f) processing the tool face to target angles at the first and second positions to determine the distance from the borehole to the subterranean structure.

31. The method of claim 30, wherein the distance from the borehole to the target subterranean structure is determined independent of azimuth values at the first and second positions of the borehole.

32. The method of claim 30, wherein the distance from the borehole to the target subterranean structure between the first and second positions in the borehole is substantially inversely proportional to the difference between the tool face to target angles at the first and second positions.

33. The method of claim 30, wherein the distance from the borehole to the subterranean structure is substantially inversely proportional to the difference between the tangent of the tool face to target angle at the second position and the tangent of the tool face to target angle at the first position.

34. The method of claim 30, wherein (f) further includes processing at least one of a relative change in horizontal position and vertical position between the first and second positions in the borehole and corresponding first and second points on the target subterranean structure, said corresponding first and second points substantially orthogonal to a longitudinal axis of the borehole at the first and second positions in the borehole.

35. The method of claim 34, wherein distances from the first and second positions in the borehole to the target subterranean structure are determined according to a set of equations selected from the group consisting of:

(1)
$$d1 = \frac{-\Delta x - \Delta y \tan(TFT2)}{\cos(TFT1)[\tan(TFT2) - \tan(TFT1)]}$$

$$d2 = \frac{-\Delta x - \Delta y \tan(TFT1)}{\cos(TFT2)[\tan(TFT2) - \tan(TFT1)]};$$

(2)
$$d1 = \frac{-\Delta y \tan(TFT2)}{\cos(TFT1)[\tan(TFT2) - \tan(TFT1)]}$$

$$d2 = \frac{-\Delta y \tan(TFT1)}{\cos(TFT2)[\tan(TFT2) - \tan(TFT1)]};$$

(3) $$d1 = \frac{-\Delta x}{\cos(TFT1)[\tan(TFT2) - \tan(TFT1)]}$$

$$d2 = \frac{-\Delta x}{\cos(TFT2)[\tan(TFT2) - \tan(TFT1)]};\text{ and}$$

(4) $$d1 = \frac{\Delta y}{\tan(\Delta TFT)}$$

$$d2 = \frac{\Delta y}{\sin(\Delta TFT)};\text{ wherein}$$

d1 and d2 represent the distances from the first and second positions in the borehole to said corresponding first and second points on the target subterranean structure, TFT1 and TFT2 represent tool face to target angles at the first and second positions, respectively, ΔTFT represents the difference between the tool face to target angles at the first and second positions, and Δx and Δy represent the relative changes in horizontal and vertical positions, respectively, between the first and second positions in the borehole and said corresponding first and second points on the target subterranean structure.

36. The method of claim 34, wherein a historical survey of the target subterranean structure is utilized to determine the relative change in horizontal position and the relative change in vertical position between the first and second positions in the borehole and said corresponding first and second points on the target subterranean structure.

37. The method of claim 34, wherein inclination values at the first and second positions in the borehole and at said corresponding first and second points on the target subterranean structure are utilized to determine the relative change in vertical position between the first and second positions in the borehole and said corresponding first and second points on the target subterranean structure.

38. The method of claim 37, wherein the relative change in vertical position between the first and second positions in the borehole and said corresponding first and second points on the target subterranean structure is determined according to the following equation:

$$\Delta y = \Delta MD(\sin(\frac{IncM1 + IncM2}{2} - \frac{IncT1 + IncT2}{2}))$$

wherein Δy represents the relative change in vertical position between the first and second positions in the borehole and said corresponding first and second points on the target subterranean structure, ΔMD represents a difference in measured depth between the first and second positions, IncM1 and IncM2 represent inclination values at the first and second positions in the borehole, and IncT1 and IncT2 represent inclination values at said corresponding first and second points on the target subterranean structure.

39. The method of claim 37, wherein the inclination values are determined via gravity measurements at the first and second positions.

40. The method of claim 34, wherein azimuth values at the first and second positions in the borehole and at said corresponding first and second points on the target

subterranean structure are utilized to determine the relative change in horizontal position between the first and second positions in the borehole and said corresponding first and second points on the target subterranean structure.

41. The method of claim 40, wherein the relative change in horizontal position between the first and second positions in the borehole and said corresponding first and second points on the target subterranean structure is determined according to the following equation:

$$\Delta x = \Delta MD(\sin(\frac{AziM1 + AziM2}{2} - \frac{AziT1 + AziT2}{2}))$$

wherein Δx represents the relative change in horizontal position between the first and second positions in the borehole and said corresponding first and second points on the target subterranean structure, ΔMD represents a difference in measured depth between the first and second positions, AziM1 and AziM2 represent azimuth values at the first and second positions in the borehole, and AziT1 and AziT2 represent azimuth values at said corresponding first and second points on the target subterranean structure.

42. The method of claim 40, wherein the azimuth values are determined via gravity measurements at the first and second positions.

43. A method for determining a local azimuth of a borehole, the method comprising:

(a) providing a downhole tool including first and second magnetic field measurement devices disposed at corresponding first and second positions in the borehole, the first and second positions selected to be within sensory range of magnetic flux from a target subterranean structure;

(b) measuring local magnetic fields at the first and second positions using the corresponding first and second magnetic field measurement devices;

(c) processing (1) the local magnetic fields at the first and second positions, and (2) a reference magnetic field, to determine a portion of the local magnetic fields attributable to the target subterranean structure;

(d) generating interference magnetic field vectors at the first and second positions from the portion of the local magnetic fields attributable to the target subterranean structure;

(e) processing the interference magnetic field vectors to determine a tool face to target angle at each of the first and second positions; and

(f) processing the tool face to target angles at the first and second positions to determine a local azimuth of the borehole.

44. The method of claim 43, wherein (f) comprises:

(1) processing the tool face to target angles at the first and second positions to determine distance from the borehole to the target subterranean structure;

(2) processing the tool face to target angles at the first and second positions and the distance from the borehole to the target subterranean structure to determine coordinates of the first and second positions in the borehole; and

(3) processing the coordinates of first and second positions in the borehole to determine a local azimuth of the borehole.

45. The method of claim 44, wherein the coordinates of the first and second positions in the borehole are determined according to the following equations:

$$PMx1 = PTx - d1\sin(TFT1)$$
$$PMy1 = PTy - d1\cos(TFT1)$$
$$PMx2 = PTy - d2\sin(TFT2)$$
$$PMy2 = PTy - d2\cos(TFT2)$$

wherein PMx1 and PMy1 represent x and y coordinates of the first position, PMx2 and PMy2 represent x and y coordinates of the second position, PTx and PTy represent x and y coordinates of the target subterranean structure, d1 and d2 represent distances from the first and second positions to the target subterranean structure, and TFT1 and TFT2 represent tool face to target angles between the first and second positions and the target subterranean structure.

46. The method of claim 44, wherein the local azimuth of the borehole is determined according to the following equation:

$$AzM = \arctan(\frac{Cy2 - Cy1}{Cx2 - Cx1})$$

where AzM represents the local azimuth of the borehole, Cx1 and Cy1 represent x and y coordinates of the first position, and Cx2 and Cy2 represent x and y coordinates of the second position.

47. A method for drilling a borehole along a predetermined course relative to a target subterranean structure, at least a portion of the borehole being within sensory range of magnetic flux from the target subterranean structure, the method comprising:

(a) providing a downhole tool including first and second magnetic field measurement devices disposed at corresponding first and second positions in the borehole, the first and second positions selected to be within sensory range of magnetic flux from the target subterranean structure;

(b) measuring local magnetic fields at the first and second positions using the corresponding first and second magnetic field measurement devices;

(c) processing (1) the local magnetic fields at the first and second positions, and (2) a reference magnetic field, to determine a portion of the local magnetic fields attributable to the subterranean target well;

(d) generating interference magnetic field vectors at the first and second positions from the portion of the local magnetic fields attributable to the target subterranean target well;

(e) processing the interference magnetic field vectors to determine a tool face to target angle at each of the first and second positions;

(f) processing the tool face to target angles at the first and second positions determined in (e) to determine a direction for subsequent drilling of the borehole; and

(g) drilling the borehole along the direction for subsequent drilling determined in (f) such that the downhole tool is repositioned at a new locus in the borehole, and the first and second positions are repositioned at corresponding new loci, the first and second magnetic field measurement devices remaining within sensory range of magnetic flux from the subterranean structure; and

(h) repeating (b), (c), (d), (e), (f), and (g).

48. The method of claim 47, wherein at least a portion of the target subterranean structure occupies pre-known subterranean space, the method further comprising:

(i) pre-generating a drilling plan for the borehole in view of the pre-known subterranean space, the drilling plan including projected tool face to target angles between the borehole and the target subterranean structure at a plurality of selected loci along the borehole.

49. The method of claim 48, wherein (f) comprises processing the tool face to target angles determined in (e) and the projected tool face to target angles in the drilling plan pre-generated in (i) to determine a direction of subsequent drilling of the borehole relative to the target subterranean structure.

50. The method of claim 47, wherein (f) further comprises:

processing the tool face to target angles at the first and second positions determined in (e) to determine distance from the borehole to the target subterranean structure.

51. The method of claim 47, wherein (f) further comprises:

(1) processing the tool face to target angles at the first and second positions determined in (e) to determine distance from the borehole to the target subterranean structure;

(2) processing the tool face to target angles at the first and second positions and the distance from the borehole to the target subterranean structure to determine coordinates of the first and second positions on the borehole; and

(3) processing the coordinates of first and second positions on the borehole to determine a local azimuth of the borehole.

52. A system for determining the location of a target subterranean structure from within an adjacent borehole, said subterranean structure generating magnetic flux, the system comprising:

a down hole tool including first and second magnetic field measurement devices deployed thereon, the tool operable to be positioned in a borehole such that the first and second magnetic field measurement devices are located at corresponding first and second positions in the borehole, the first and second positions selected to be within sensory range of magnetic flux from the subterranean structure; and

a processor configured to determine:

(A) local magnetic fields at the first and second positions as measured using the corresponding first and second magnetic field measurement devices;

(B) a portion of the local magnetic fields attributable to the subterranean structure at each of the first and second positions, said portion determined from the local magnetic fields in (A) and a reference magnetic field made available to the processor;

(C) an interference magnetic field vector at each of the first and second positions, each of the interference magnetic field vectors corresponding to the portion of the local magnetic fields determined in (B); and

(D) a tool face to target angle at each of the first and second positions, the tool face to target angles representing a corresponding direction from first and second positions in the borehole to the subterranean structure.

53. The system of claim 52, comprising first and second gravity measurement devices disposed at the first and second positions, respectively.

54. The system of claim 52, wherein:

each of the magnetic field measurement devices comprises first, second, and third magnetometers;

each of the gravity measurement devices comprises first, second, and third accelerometers;

55. A computer system comprising:

at least one processor; and

a storage device having computer-readable logic stored thereon, the computer-readable logic accessible by and intelligible to the processor;

the processor further disposed to receive input from first and second magnetic field measurement devices when said first and second magnetic field measurement devices are deployed on a downhole tool at corresponding first and second positions in a borehole, the first and second positions selected to be within sensory range of magnetic flux generated by a target subterranean structure located outside the borehole,

the computer-readable logic further configured to instruct the processor to execute a method for determining the location of the target subterranean structure, the method comprising:

(a) determining a local magnetic field at each of the first and second positions based on input from the corresponding first and second magnetic field measurement devices;

(b) determining a portion of the local magnetic field attributable to the subterranean structure at each of the first and second positions, said portion determined from the local magnetic fields in (a) and a reference magnetic field made available to the processor;

(c) calculating an interference magnetic field vector for each of the first and second positions, each of the interference magnetic field vectors corresponding to the portion of the local magnetic fields determined in (b); and

(d) determining tool face to target angles at each of the first and second positions, the tool face to target angles representing a corresponding direction

between the first and second positions in the borehole to the subterranean structure.

56. The computer system of claim 55, wherein the portion of the total magnetic field attributable to the subterranean structure at each locus in (b) is determined by the equations:

$$M_{IX} = B_X - M_{EX}$$

$$M_{IY} = B_Y - M_{EY}$$

wherein Mix and Miy represent x and y components, respectively, of the portion of the total magnetic field attributable to the subterranean structure, and Bx and By represent x and y components of the total magnetic field determined in (a), and Mex and Mey represent the x and y components of the reference magnetic field.

57. The computer system of claim 55, wherein the tool face to target angle at each of the first and second positions is determined in (d) according to the equation:

$$TFT = \arctan(\frac{M_{IX}}{M_{IY}}) + \arctan(\frac{Gx}{Gy})$$

wherein TFT represents the tool face to target angle, Mix and Miy represent the x and y components, respectively, of the magnetic interference vector, and Gx and Gy represent x and y components of gravity vectors measured at at least one of the first and second positions.

58. The computer system of claim 55, wherein the computer system further comprises a display apparatus and the method further comprises

(e) displaying the tool face to target angles versus a measured depth of the borehole.

59. The computer system of claim 55, wherein the method further comprises:

(e) processing the tool face to target angles determined in (d) to determine a local direction of the borehole relative to the target subterranean structure; and

(f) processing the tool face to target angles determined in (d) and the local direction of the borehole determined in (f) to determine a subsequent direction of drilling the borehole.

60. The computer system of claim 55, wherein the method further comprises:

(e) processing the tool face to target angles determined in (d) to determine distances from the first and second positions in the borehole to the subterranean structure.

61. The computer system of claim 60, wherein the distances from the first and second positions in the borehole to the subterranean structure are determined according to a set of equations selected from the group consisting of:

(1) $$d1 = \frac{-\Delta x - \Delta y \tan(TFT2)}{\cos(TFT1)[\tan(TFT2) - \tan(TFT1)]}$$

$$d2 = \frac{-\Delta x - \Delta y \tan(TFT1)}{\cos(TFT2)[\tan(TFT2) - \tan(TFT1)]};$$

(2) $$d1 = \frac{-\Delta y \tan(TFT2)}{\cos(TFT1)[\tan(TFT2) - \tan(TFT1)]}$$

$$d2 = \frac{-\Delta y \tan(TFT1)}{\cos(TFT2)[\tan(TFT2) - \tan(TFT1)]};$$

(3) $$d1 = \frac{-\Delta x}{\cos(TFT1)[\tan(TFT2) - \tan(TFT1)]}$$

$$d2 = \frac{-\Delta x}{\cos(TFT2)[\tan(TFT2) - \tan(TFT1)]};\ \text{and}$$

(4) $$d1 = \frac{\Delta y}{\tan(\Delta TFT)}$$

$$d2 = \frac{\Delta y}{\sin(\Delta TFT)};\ \text{wherein}$$

d1 and d2 represent the distances from the first and second positions in the borehole to the target subterranean structure, TFT1 and TFT2 represent tool face to target angles at the first and second positions, respectively, ΔTFT represents the difference between the tool face to target angles at the first and second positions, and Δx and Δy represent the relative changes in horizontal and vertical positions, respectively, between the first and second positions in the borehole and corresponding first and second points on the subterranean structure, said corresponding first and second points substantially orthogonal to a longitudinal axis of the borehole at the first and second positions in the borehole.

62. The computer system of claim 61, wherein Δx and Δy are determined according to the following equations:

$$\Delta x = \Delta MD(\sin(\frac{AziM1 + AziM2}{2} - \frac{AziT1 + AziT2}{2}))$$

$$\Delta y = \Delta MD(\sin(\frac{IncM1 + IncM2}{2} - \frac{IncT1 + IncT2}{2}))$$

wherein ΔMD represents a difference in measured depth between the first and second positions, IncM1 and IncM2 and AziM1 and AziM2 represent inclination and

azimuth values, respectively, at the first and second positions in the borehole, and IncT1 and IncT2 and AziT1 and Azit2 represent inclination and azimuth values, respectively, values at said corresponding first and second points on the subterranean structure.

63. The computer system of claim 55, wherein the method further comprises:

(e) processing the tool face to target angles determined in (d) to determine distance from the borehole to the subterranean structure;

(f) processing the tool face to target angles determined in (d) and the distance from the borehole to the subterranean structure determined in (e) to determine coordinates of the first and second positions in the borehole; and

(g) processing the coordinates of first and second positions in the borehole determined in (f) to determine a local azimuth of the borehole.

64. The computer system of claim 63, wherein:

the coordinates of the first and second positions in the borehole are determined in (f) according to the following equations:

$$
\begin{aligned}
PMx1 &= PTx - d1\sin(TFT1) \\
PMy1 &= PTy - d1\cos(TFT1) \\
PMx2 &= PTy - d2\sin(TFT2) \\
PMy2 &= PTy - d2\cos(TFT2)
\end{aligned}
$$

wherein PMx1 and PMy1 represent x and y coordinates of the first position, PMx2 and PMy2 represent x and y coordinates of the second position, PTx and PTy represent x and y coordinates of the subterranean structure, d1 and d2 represent distances from the first and second positions to the subterranean structure, and TFT1 and TFT2 represent

tool face to target angles between the first and second positions and the subterranean structure; and

wherein the local azimuth of the borehole is determined in (g) according to the following equation:

$$AzM = \arctan(\frac{Cy2 - Cy1}{Cx2 - Cx1})$$

where AzM represents the local azimuth of the borehole, Cx1 and Cy1 represent x and y coordinates of the first position in a conventional coordinates system, and Cx2 and Cy2 represent x and y coordinates of the first position in the conventional coordinates system.